



National Assessment of Energy Storage for Grid Balancing and Arbitrage

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Energy Storage Analytics Agenda



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2011 2012 2013 2014 2015 Systems Analysis National Assessment of Regional Storage Potential Distributed vs. Central Storage Grid Modelin Benefits Regional Cost & Systems Analysis: Hawaii Performance Other Regional Analysis Regional Case Nevada Targets Studies Value & Component Cost Redox Flow Cost Cost Models for Other Storage Refine and Exercise Model Technologies Models Analysis Implement Manufacturing Flow Manufacturing Analysis for Other Storage Manufacturing Cost Analysis Analysis Technologies Improvements Standards Gap System Performance Proposal of Standards Enhancement Planning & Operations Analysis **Testing Development** Standards & Maintenance Development Planning and Understanding Current Planning Development of Stochastic Operation and Planning Operational and Operation Methodologies Methodologies Methodologies ES-Select & Energy Identifying Planning and Storage Production Development of Planning Tools gaps for Database & Cost Operational Tools planning tools Handbook Modeling Markets & Policy PUC Regulatory Ancillary Service Policy Market conditioning and Markets & Policy Analysis Market Structures Analysis education

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National Assessment of Energy Storage Considering Regional Differences



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► Objectives: Determine:

future balancing requirements needed by 2020 to accommodate assumed 20% RPS,

market size for storage and respective cost targets for balancing and energy arbitrage by regions

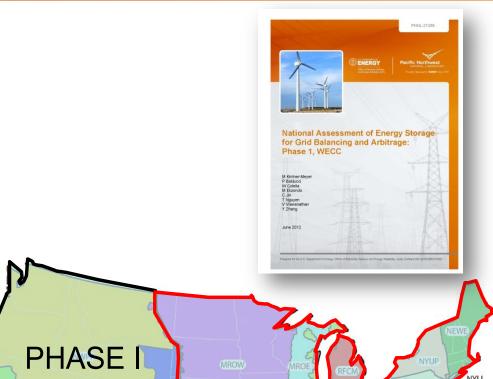
most cost-effective technologies to meet add'l balancing requirements.

► Value:

 Provides plausible market potential estimates of energy storage for the investment community and policy makers in a nine-year forecasting time horizon (2020)

▶ Differentiates markets for short- (< 1h) and longer-term storage (>4 hours)

▶ Reveals key assumptions and their influence on the outcome of the analysis



PHASE II

EIC + ERCOT

WECC

Additional Wind Capacity WECC for a 2020 Grid Scenario



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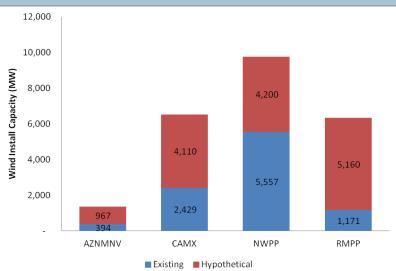
Hypothetical Wind Site

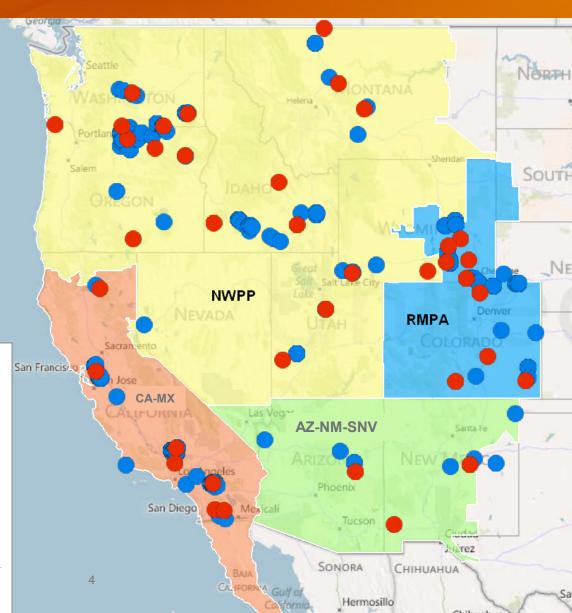
WECC-wide Wind capacity

- Existing (2010): 9.6 GW

- New (2011-2020): 14.4 GW

Total wind capacity: 24.0 GW

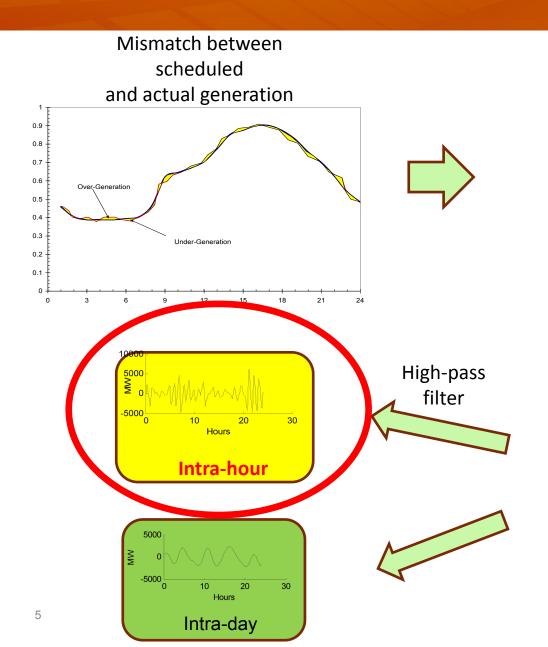


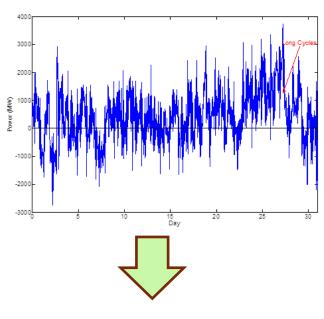


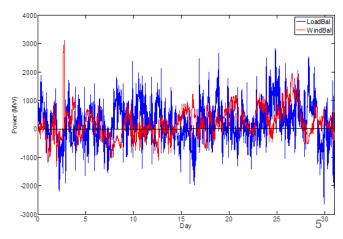
Definition of Intra-hour Balancing Services



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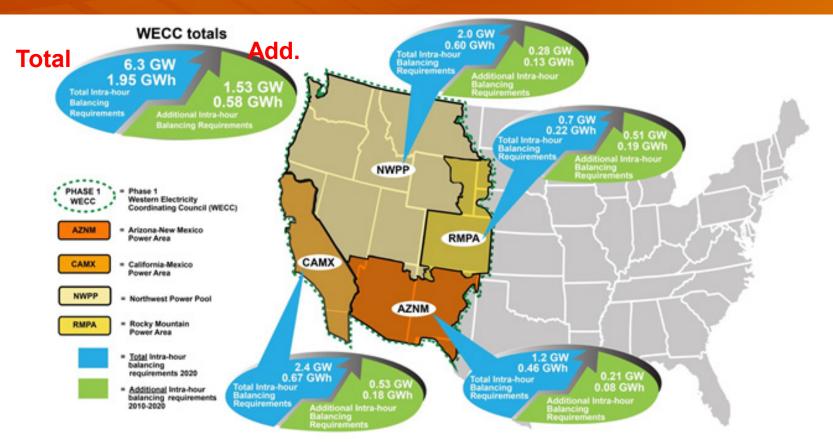




Balancing Requirements: WECC



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- ▶ Additional Intra-hour Balancing Requirements: 1.53 GW, 0.58 GWh (~20 minutes)
- ▶ **Total** Intra-hour Balancing Requirements: 6.3 GW, 1.95 GWh (~20 minutes)
- For every one unit of wind capacity power, approximately 0.06 to 0.21 units of intra-hour balancing

Technology Options to Meet Balancing Requirements



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- What are the most cost-effective technology options for serving balancing requirements?
 - Na-S (Sodium Sulphur) batteries
 - Li-lon (Lithium Ion batteries)
 - Flywheel
 - CAES (Compressed Air Energy Storage)
 - Redox-Flow batteries
 - Pumped Hydro Storage
 - Demand Response and
 - Combustion turbine as a base-case technology
 - Hybrid-energy storage system (combining fast and slower reacting components)









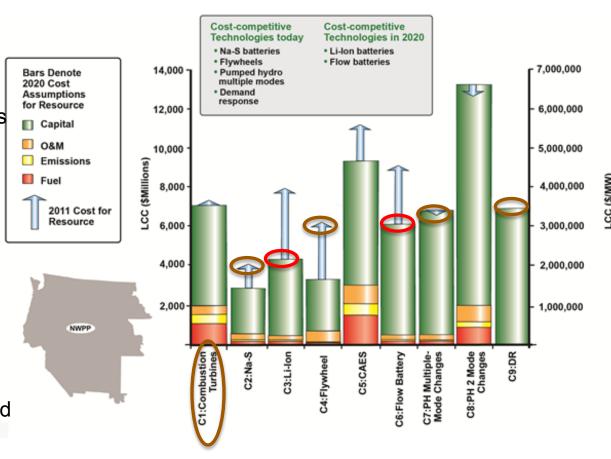
National Assessment for Energy Storage (Phase I) **Key Findings**



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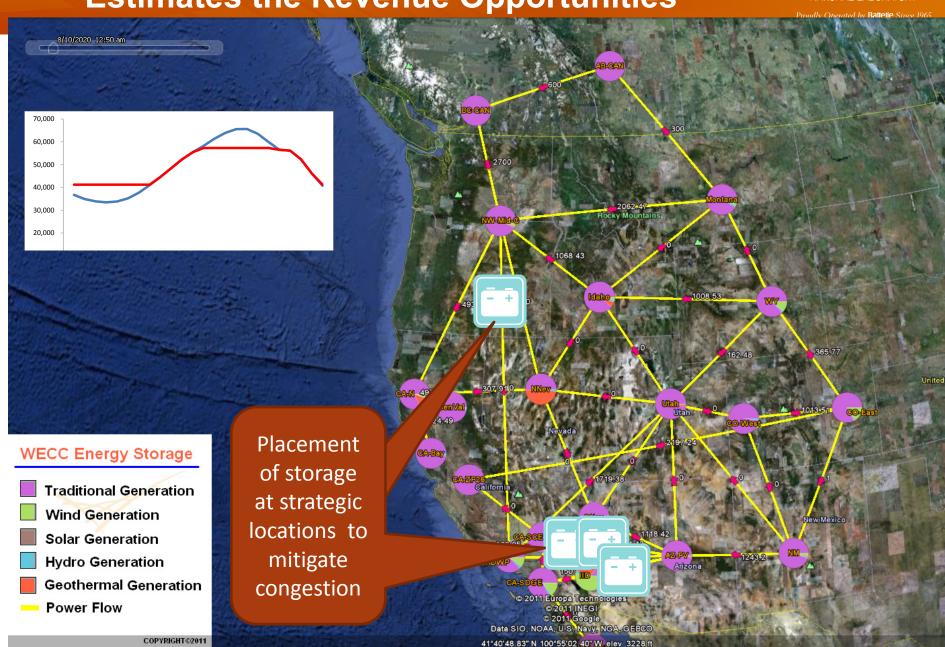
Life Cycle Costs

- Results from detailed analysis indicate the most cost-effective technological solutions for meeting balancing requirements
 - Today are:
 - Na-S batteries
 - Flywheels
 - Pumped hydro
 - Demand response (EV smart charging)
 - **Ey 2020**:
 - Li-ion batteries
 - Redox flow batteries
- Competitiveness of storage will improve as the cost of advanced technology is expected to decline in the next 10 years



Detailed Production Cost Modeling Estimates the Revenue Opportunities

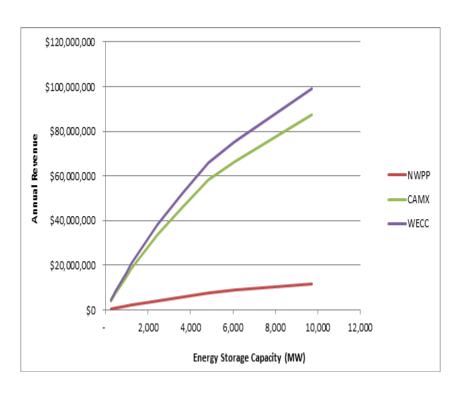


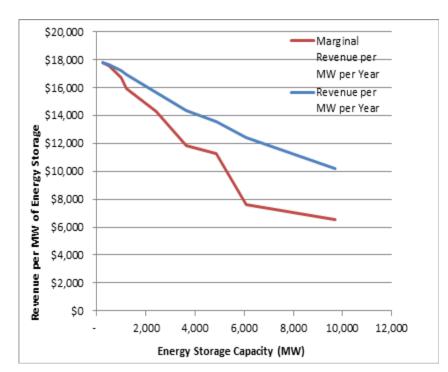


Revenue Expectations from Energy Arbitrage



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Key Outcomes

- Wholesale <u>energy value</u> is low and is insufficient to solely justify storage >1 hour
- <u>Capacity value</u> necessary for business case of storage >> 1hour

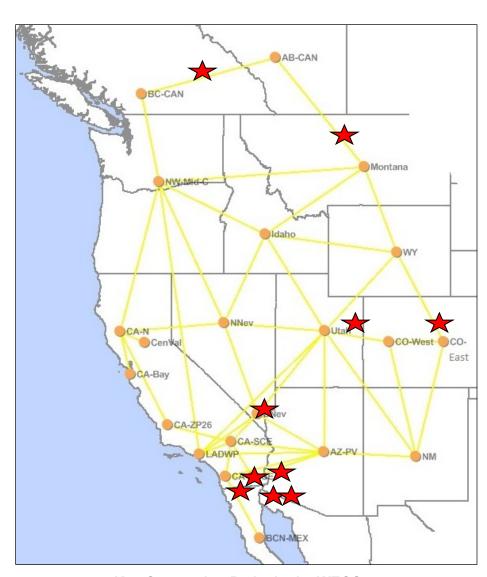
National Assessment for Energy Storage (Phase I) **Key Findings: Arbitrage Services**



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Arbitrage Opportunities

- Arbitrage revenue expectations fall far short of levels required for capital recovery
- Much larger market size for energy storage is possible in WECC if price points are reached
 - \$90/kWh is the price point for arbitrage assuming a capacity credits of \$150/kW/year for Li-lon, NaS and flywheels
 - This analysis is limited, excluding several potential value streams (e.g., power quality, and T&D deferral)



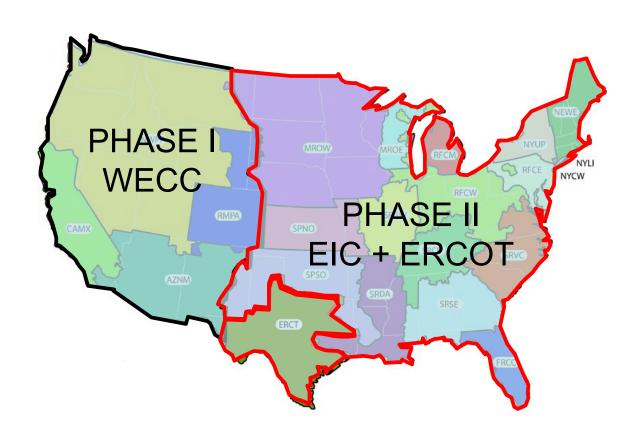
Key Congestion Paths in the WECC



Completion of National Assessment Phase II in December 2012

National Assessment: Phase I- Report available at:

http://energyenvironment.pnnl.gov/pdf/P NNL-21388 National Assessment Storage Phase 1 final.pdf



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